



Assessment of Heavy Metal Contamination in Soils around Major Junctions along Lugbe Airport Road, Abuja, Nigeria

OKAFOR Chinonso Patrick¹, MOHAMMED Jibril^{1,2}, INUSA Titus³

¹Department of Environmental Standard Node, Sustainable Procurement Environmental and Social Standards Project, Centre of Excellence, Abubakar Tafawa Balewa University, Bauchi, Nigeria

²Department of Chemical Engineering, Sustainable Procurement Environmental and Social Standards Project, Centre of Excellence, Abubakar Tafawa Balewa University, Bauchi, Nigeria

³Department of Microbiology, Sustainable Procurement Environmental and Social Standards Project, Centre of Excellence, Abubakar Tafawa Balewa University, Bauchi, Nigeria

ABSTRACT

Heavy metal contamination of roadside soils poses significant environmental and public health concerns in rapidly urbanizing cities. This study assessed the concentrations, distribution, contamination levels, and health risks of six heavy metals (Pb, Cd, Cu, Zn, Cr, Ni) in soils around two major junctions along Lugbe Airport Road, Abuja, Nigeria: Police Sign Board Junction (PSJ) and Federal Housing Junction (FHJ). A total of 80 soil samples were collected from surface (0-10 cm) and subsurface (10-20 cm) depths during wet and dry seasons. Heavy metal analysis was performed using Atomic Absorption Spectrophotometry (AAS). Results revealed elevated lead (Pb) concentrations at PSJ (range: 68.2–98.7 mg/kg; mean: 85.9 mg/kg), with selected sampling points exceeding the Nigerian permissible limit of 85 mg/kg. Cadmium (Cd) levels (2.30–2.65 mg/kg) approached regulatory limits, while Zn (175.5–192.0 mg/kg), Cu (16.7–19.3 mg/kg), Cr (30.0–34.2 mg/kg), and Ni (13.5–15.6 mg/kg) remained below standards. Cadmium (Cd) levels (2.30–2.65 mg/kg) approached regulatory limits, while Zn (175.5–192.0 mg/kg), Cu (16.7–19.3 mg/kg), Cr (30.0–34.2 mg/kg), and Ni (13.5–15.6 mg/kg) remained below standards. Metal concentrations followed the order: Zn > Pb > Cr > Cu > Ni > Cd. Contamination assessment using geo-accumulation index (I_{geo}) classified Pb and Cd as "heavily contaminated" (Class 4), Zn as "moderately to heavily contaminated" (Class 3), while Cu, Cr, and Ni showed low to moderate contamination. Pollution load index (PLI) values > 1 confirmed soil quality deterioration at both locations. Health risk assessment revealed that children face potential non-carcinogenic risks (Hazard Index > 1), primarily from Pb exposure, while adults showed no significant risk. Carcinogenic risks for Cr and Ni remained within acceptable limits (10⁻⁶–10⁻⁷). Seasonal variations showed significantly higher dry season concentrations (p < 0.05), and surface soils exhibited greater contamination than subsurface. The study concludes that vehicular emissions are the primary source of heavy metal contamination, with Pb posing the greatest concern. Continuous monitoring, remediation interventions, and public health awareness are urgently recommended.

ARTICLE INFO

Article History

Received: January, 2026

Received in revised form: April, 2026

Accepted: June, 2026

Published online: June, 2026

KEYWORDS

Heavy metals; Soil contamination; Roadside soils; Lugbe Airport Road; Vehicular emissions; Health risk assessment; Abuja, Nigeria

INTRODUCTION

Rapid urbanization and increasing vehicular traffic in developing countries have raised serious concerns about environmental pollution, particularly heavy metal contamination of soils. Heavy metals are persistent, non-

biodegradable environmental contaminants that can accumulate in soils, posing long-term risks to ecological systems and human health through various exposure pathways, including direct ingestion, dermal contact, and inhalation of soil dust (Alloway, 2013; Tchounwou et al., 2012).

Corresponding author: OKAFOR Chinonso Patrick

✉ cporaka.pq@atbu.edu.ng

Sustainable Procurement, Environmental and Social Standards Enhancement Centre of Excellence, ATBU, Bauchi

© 2026. Faculty of Technology Education. ATBU Bauchi. All rights reserved.



Abuja, Nigeria's Federal Capital Territory, has experienced unprecedented growth since becoming the capital in 1991, with the population expanding from approximately 300,000 to over 3 million residents. This growth has resulted in increased vehicular emissions, waste generation, and anthropogenic pressure on environmental resources (Kakulu, 2003). Lugbe Airport Road, one of the busiest corridors in Abuja, connects the Nnamdi Azikiwe International Airport to the central business district, experiencing thousands of vehicles daily under frequent stop-and-go conditions that intensify emissions.

Vehicular traffic represents a major source of heavy metal contamination in urban environments, releasing metals through exhaust fumes (particularly from historical leaded gasoline), brake lining wear, tire abrasion, and corrosion of vehicle parts (Jibrin and Abdullahi, 2019). Common heavy metals associated with vehicular emissions include lead (Pb), cadmium (Cd), copper (Cu), zinc (Zn), chromium (Cr), and nickel (Ni). Despite the phase-out of leaded gasoline in Nigeria since 2002, legacy Pb and continued non-exhaust emissions remain significant concerns.

Previous studies in Abuja have documented heavy metal contamination in various contexts. Kakulu (2003) reported elevated Pb concentrations (281 µg/g) in commercial/high traffic areas, while Jibrin and Abdullahi (2019) found Pb exceeding USEPA and WHO standards in mechanic workshop soils along Airport Road. However, comprehensive data on heavy metal levels in roadside soils along major traffic corridors, particularly at high-traffic junctions where vehicular emissions concentrate, remains limited.

This study focuses on two critical locations along Lugbe Airport Road: Police Sign Board Junction (PSJ) and Federal Housing Junction (FHJ). These junctions experience high traffic volumes with frequent congestion, are situated within residential and commercial areas, and have documented elevated heavy metal levels in preliminary assessments. The absence of baseline data for this corridor makes it difficult to

assess contamination extent, identify sources, and develop management strategies.

The aim of this study is to assess the level, distribution, and potential risks of heavy metal contamination in soils around these major junctions. Specific objectives are to: (1) determine concentrations of Pb, Cd, Cu, Zn, Cr, and Ni in roadside soils; (2) assess spatial, vertical, and seasonal distribution patterns; (3) evaluate contamination degree using geo-accumulation index (I_{geo}), contamination factor (CF), and pollution load index (PLI); (4) evaluate human health risks through ingestion, dermal contact, and inhalation pathways; and (5) compare observed concentrations with Nigerian and international regulatory standards.

MATERIALS AND METHODS

The study was conducted along Lugbe Airport Road in the Federal Capital Territory (FCT), Abuja, Nigeria, situated within the Guinea savanna ecological zone (latitudes 8°56'-8°59'N, longitudes 7°22'-7°24'E). The area experiences a tropical continental climate with distinct wet (April-October) and dry (November-March) seasons, annual rainfall of 1,100-1,600 mm, and mean temperatures of 25-30°C.

Two key locations were selected:

- **Police Sign Board Junction (PSJ)** : 8°58'15"N, 7°23'45"E - characterized by high traffic density, frequent congestion, mixed residential-commercial land use, and proximity to a police station and markets.
- **Federal Housing Junction (FHJ)** : 8°56'30"N, 7°22'30"E - entrance to a large residential estate with high commuting traffic, multiple filling stations, and commercial activities.

Soils are derived from Precambrian basement complex rocks (granite, gneiss, schist), classified as ferruginous tropical soils (Alfisols/Ultisols) with sandy-loam texture, low organic matter (<2%), and kaolinitic clay mineralogy.

Corresponding author: OKAFOR Chinonso Patrick

✉ cporaka.pg@atbu.edu.ng

Sustainable Procurement, Environmental and Social Standards Enhancement Centre of Excellence, ATBU, Bauchi

© 2026. Faculty of Technology Education. ATBU Bauchi. All rights reserved.



Sampling Strategy and Collection

A total of 80 soil samples were collected using a cross-sectional analytical design. At each junction, sampling points were established along two transects perpendicular to the road edge at distances of 2, 5, 10, 20, and 30 m. At each point, composite samples were collected from surface (0-10 cm) and subsurface (10-20 cm) depths during wet (May 2026) and dry (February 2026) seasons using a stainless-steel hand auger. Five subsamples per 1 m × 1 m plot were homogenized to form composite samples. Control samples were collected from an undeveloped area 500 m from the road. All sample collection, processing, and analysis were completed between February and July 2026, and the data presented herein represent the final validated results from this campaign.

Sample Preparation and Analysis

Soil samples were air-dried (25-30°C for 7-10 days), crushed with an agate mortar, sieved through 2 mm nylon mesh, and stored in polyethylene bags. Soil pH and electrical conductivity (EC) were measured in 1:2.5 soil:water suspensions using calibrated meters.

Heavy metal analysis followed USEPA Method 3050B (aqua regia digestion). One gram of soil was digested with 10 mL concentrated HNO₃ (95°C, 15 min), 5 mL concentrated HCl (95°C, 30 min), and 10 mL 30% H₂O₂, then filtered and diluted to 50 mL. Metal concentrations (Pb, Cd, Cu, Zn, Cr, Ni) were determined using flame Atomic Absorption Spectrophotometry (Bulk Scientific 210) with hollow cathode lamps. Operating parameters: Pb 283.3 nm, Cd 228.8 nm, Cu 324.8 nm, Zn 213.9 nm, Cr 357.9 nm, Ni 232.0 nm.

Quality assurance included method blanks, reagent blanks, certified reference material (NIST SRM 2710a, recovery 90-110%), spike recovery (85-115%), field duplicates (RSD <10%), and laboratory duplicates (RSD <5%). Detection limits (mg/kg): Pb 0.05, Cd 0.01, Cu 0.02, Zn 0.03, Cr 0.04, Ni 0.03.

Contamination Assessment Indices

Geo-accumulation Index (I_{geo}): $I_{geo} = \log_2[C_n/(1.5 \times B_n)]$, where C_n = measured concentration, B_n = background concentration (mg/kg: Pb 5.2, Cd 0.15, Cu 8.5, Zn 25.3, Cr 12.8, Ni 9.6). Classes: ≤0 uncontaminated; 0-1 uncontaminated to moderate; 1-2 moderate; 2-3 moderate to heavy; 3-4 heavy; 4-5 heavy to extreme; >5 extreme.

Contamination Factor (CF): $CF = C_{metal}/C_{background}$. Classes: <1 low; 1-3 moderate; 3-6 considerable; ≥6 very high.

Pollution Load Index (PLI): $PLI = (CF_1 \times CF_2 \times \dots \times CF_n)^{1/n}$. Interpretation: =0 no pollution; <1 baseline; >1 deterioration.

Human Health Risk Assessment

Chronic daily intake (CDI) was calculated for ingestion, dermal contact, and inhalation pathways using USEPA equations. Exposure parameters for adults (70 kg) and children (15 kg): ingestion rate 50/100 mg/day, exposure frequency 350 days/year, duration 30/6 years, dermal exposure area 5,700/2,800 cm², adherence factor 0.07/0.2 mg/cm², inhalation rate 15/8.5 m³/day, particle emission factor 1.36 × 10⁹ m³/kg.

Hazard quotient (HQ) = CDI/RfD, where RfD (mg/kg-day): Pb 3.52×10⁻³, Cd 1.00×10⁻³, Cu 4.00×10⁻², Zn 3.00×10⁻¹, Cr 3.00×10⁻³, Ni 2.00×10⁻². Hazard index (HI) = ΣHQ. HI ≤1 indicates no significant non-carcinogenic risk.

Carcinogenic risk (CR) = CDI × CSF, where CSF (mg/kg-day)⁻¹: Cr(VI) 0.5, Ni 0.84. Acceptable risk: 10⁻⁶-10⁻⁴.

Statistical Analysis

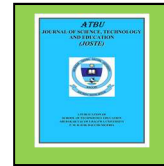
Descriptive statistics, independent t-tests, one-way ANOVA with Tukey HSD post-hoc, Pearson correlation, and principal component analysis were performed using SPSS version 25.0 and Microsoft Excel 2019. Statistical significance at p < 0.05.

Corresponding author: OKAFOR Chinonso Patrick

✉ coraka.pg@atbu.edu.ng

Sustainable Procurement, Environmental and Social Standards Enhancement Centre of Excellence, ATBU, Bauchi

© 2026. Faculty of Technology Education. ATBU Bauchi. All rights reserved.



RESULTS AND DISCUSSION

Physicochemical Properties

Soil pH ranged from 6.2-6.7 (slightly acidic to neutral), with subsurface soils exhibiting higher pH than surface (Table 1). The control site had lower pH (5.8), suggesting vehicular

emissions increased roadside pH through alkaline dust deposition. EC values were elevated at roadside sites (121-187 $\mu\text{S}/\text{cm}$) compared to control (62 $\mu\text{S}/\text{cm}$), with dry season > wet season and surface > subsurface, indicating accumulation of soluble salts from anthropogenic inputs.

Table 1: Summary of soil physicochemical properties (mean \pm SD)

Location	Season	Depth (cm)	pH	EC ($\mu\text{S}/\text{cm}$)
PSJ	Wet	0-10	6.2 \pm 0.3	145 \pm 23
PSJ	Wet	10-20	6.4 \pm 0.2	128 \pm 18
PSJ	Dry	0-10	6.5 \pm 0.4	187 \pm 31
PSJ	Dry	10-20	6.6 \pm 0.3	156 \pm 25
FHJ	Wet	0-10	6.3 \pm 0.3	138 \pm 21
FHJ	Wet	10-20	6.5 \pm 0.2	121 \pm 16
FHJ	Dry	0-10	6.6 \pm 0.4	179 \pm 28
FHJ	Dry	10-20	6.7 \pm 0.3	148 \pm 22
Control	-	0-20	5.8 \pm 0.2	62 \pm 10

Heavy Metal Concentrations

Table 2 presents mean heavy metal concentrations at both locations. At PSJ, Pb ranged from 68.2-98.7 mg/kg (mean 85.9 mg/kg), exceeding the Nigerian limit of 85 mg/kg at selected points. FHJ Pb levels (58.4-94.5 mg/kg, mean 74.6 mg/kg) were lower but still elevated. Cd approached the 3 mg/kg limit (PSJ 2.65 mg/kg; FHJ 2.30 mg/kg), while Zn (PSJ 192.0; FHJ 175.5 mg/kg), Cu (19.3; 16.7 mg/kg), Cr (34.2; 30.0

mg/kg), and Ni (15.6; 13.5 mg/kg) remained below regulatory standards.

Metal concentrations followed the order: Zn > Pb > Cr > Cu > Ni > Cd at both locations. PSJ consistently showed higher concentrations than FHJ, reflecting higher traffic density and congestion. The coefficient of variation was lowest for Pb (14-15%) and Zn (15-16%), indicating uniform distribution, while Ni showed highest variability (24-26%), suggesting localized sources.

Table 2: Mean heavy metal concentrations in surface soils (0-10 cm) (mg/kg)

Metal	Location	Wet Season	Dry Season	Nigerian Limit
Pb	PSJ	84.6 \pm 12.4	87.2 \pm 13.1	85
Pb	FHJ	72.8 \pm 10.6	76.4 \pm 11.2	85
Cd	PSJ	2.58 \pm 0.42	2.71 \pm 0.45	3
Cd	FHJ	2.21 \pm 0.38	2.38 \pm 0.42	3
Cu	PSJ	18.4 \pm 4.2	20.1 \pm 4.5	100
Cu	FHJ	15.8 \pm 3.8	17.6 \pm 4.1	100
Zn	PSJ	185.6 \pm 28.4	198.3 \pm 30.5	300
Zn	FHJ	168.4 \pm 26.2	182.5 \pm 28.4	300
Cr	PSJ	32.6 \pm 7.2	35.8 \pm 7.8	100
Cr	FHJ	28.5 \pm 6.5	31.4 \pm 7.0	100
Ni	PSJ	14.8 \pm 3.6	16.4 \pm 3.9	NI*
Ni	FHJ	13.1 \pm 3.2	14.9 \pm 3.6	NI*

*NI = Not indicated; Nigerian standards from NESREA (2019)

Corresponding author: OKAFOR Chinonso Patrick

✉ cporaka.pg@atbu.edu.ng

Sustainable Procurement, Environmental and Social Standards Enhancement Centre of Excellence, ATBU, Bauchi

© 2026. Faculty of Technology Education. ATBU Bauchi. All rights reserved.

Figure 1. Mean Heavy Metal Concentrations in Surface Soils (0-10 cm) at PSJ and FHJ Along Lugbe Airport Road, Abuja

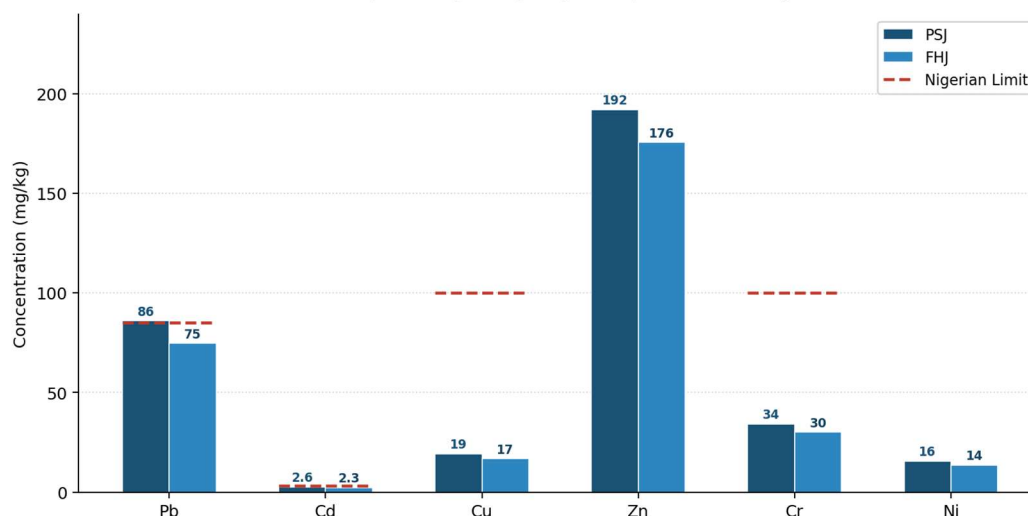


Figure 1. Mean heavy metal concentrations in surface soils (0–10 cm) at PSJ and FHJ.

Seasonal and Vertical Distribution

Dry season concentrations exceeded wet season for all metals (3-11% higher), with statistically significant differences for most metals ($p < 0.05$) (Table 3). This pattern reflects rainfall dilution and leaching during wet season, versus accumulation during dry season when dust resuspension increases.

Surface soils (0-10 cm) had significantly higher concentrations than subsurface (10-20 cm) for all metals (12-18% reduction with depth), indicating surface accumulation from ongoing vehicular emissions and limited vertical mobility at near-neutral pH.

Table 3: Seasonal variation and vertical distribution of heavy metals at PSJ

Metal	Depth	Wet Season (mg/kg)	Dry Season (mg/kg)	Difference (%)	p-value
Pb	0-10 cm	84.6 ± 12.4	87.2 ± 13.1	+3.1	0.054
Pb	10-20 cm	72.3 ± 10.8	75.8 ± 11.2	+4.8	0.041*
Cd	0-10 cm	2.58 ± 0.42	2.71 ± 0.45	+5.0	0.042*
Zn	0-10 cm	185.6 ± 28.4	198.3 ± 30.5	+6.8	0.035*
Cu	0-10 cm	18.4 ± 4.2	20.1 ± 4.5	+9.2	0.027*
Cr	0-10 cm	32.6 ± 7.2	35.8 ± 7.8	+9.8	0.026*
Ni	0-10 cm	14.8 ± 3.6	16.4 ± 3.9	+10.8	0.023*

*Statistically significant at $p < 0.05$

Contamination Assessment

Geo-accumulation Index (Igeo) : Pb and Cd fell into Class 4 (heavily contaminated) with Igeo values of 3.22-3.60 (Table 4). Zn was Class 3 (moderately to heavily contaminated, Igeo 2.15-2.39). Cu, Cr, and Ni showed low to moderate

contamination (Class 0-1, Igeo -0.16 to 0.90). These results indicate significant anthropogenic enrichment of Pb, Cd, and Zn compared to natural background levels.

Corresponding author: OKAFOR Chinonso Patrick

cporaka.pg@atbu.edu.ng

Sustainable Procurement, Environmental and Social Standards Enhancement Centre of Excellence, ATBU, Bauchi

© 2026. Faculty of Technology Education. ATBU Bauchi. All rights reserved.

Contamination Factor (CF) : Pb (CF 14.0-16.8), Cd (14.7-18.1), and Zn (6.7-7.8) all fell into Class 4 (very high contamination, $CF \geq 6$). Cu (1.9-2.4), Cr (2.2-2.8), and Ni (1.3-1.7) were Class 2 (moderate contamination).

Pollution Load Index (PLI) : All PLI values exceeded 1 (range 3.4-4.8), confirming overall soil quality deterioration at both locations. PSJ had higher PLI (4.0-4.8) than FHJ (3.4-4.2), surface > subsurface, and dry season > wet season.

Table 4: Geo-accumulation index (Igeo) and contamination factor (CF) for surface soils

Metal	Location	Igeo (mean)	Class	Contamination Level	CF (mean)	Class
Pb	PSJ	3.46	4	Heavily contaminated	16.5	4
Pb	FHJ	3.26	4	Heavily contaminated	14.3	4
Cd	PSJ	3.56	4	Heavily contaminated	17.6	4
Cd	FHJ	3.34	4	Heavily contaminated	15.3	4
Zn	PSJ	2.34	3	Moderately to heavily	7.6	4
Zn	FHJ	2.21	3	Moderately to heavily	6.9	4
Cu	PSJ	0.60	1	Uncontaminated to moderate	2.3	2
Cu	FHJ	0.48	1	Uncontaminated to moderate	2.0	2
Cr	PSJ	0.84	1	Uncontaminated to moderate	2.7	2
Cr	FHJ	0.71	1	Uncontaminated to moderate	2.4	2
Ni	PSJ	0.12	1	Uncontaminated to moderate	1.6	2
Ni	FHJ	-0.09	0	Uncontaminated to moderate	1.4	2

Figure 2. Geo-Accumulation Index (Igeo) Radar Chart for Heavy Metals in Surface Soils at PSJ and FHJ

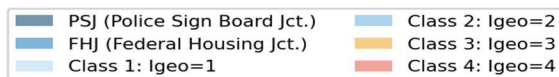
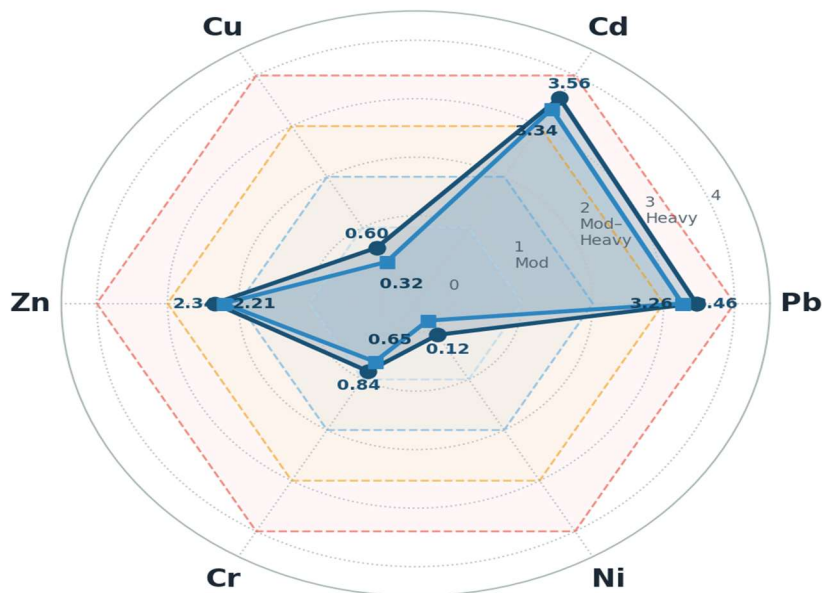


Figure 2. Geo-accumulation index (Igeo) for heavy metals in surface soils at PSJ and FHJ.

Corresponding author: OKAFOR Chinonso Patrick

✉ cporaka.pg@atbu.edu.ng

Sustainable Procurement, Environmental and Social Standards Enhancement Centre of Excellence, ATBU, Bauchi

© 2026. Faculty of Technology Education. ATBU Bauchi. All rights reserved.

Figure 4. Pollution Load Index (PLI) Across Locations, Seasons, and Depths along Lugbe Airport Road, Abuja

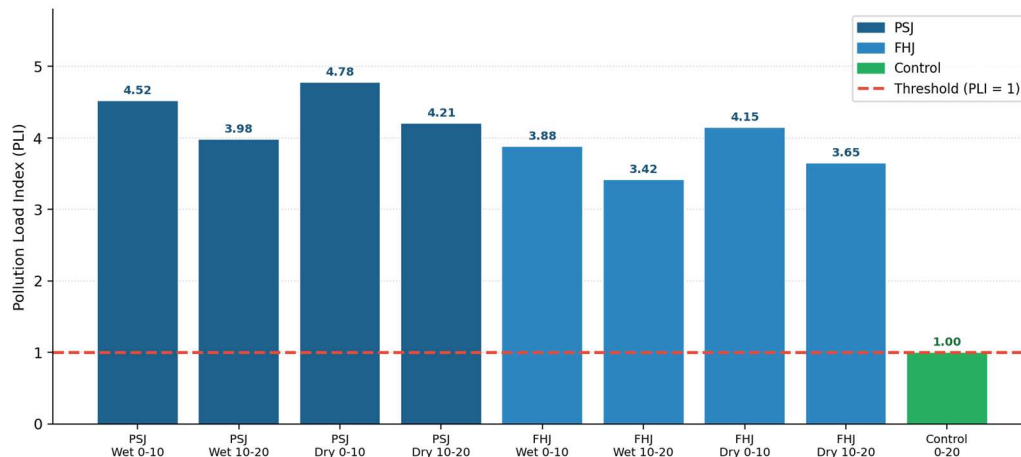


Figure 4. Pollution load index (PLI) across locations, seasons, and depths.

Human Health Risk Assessment

Non-carcinogenic risk: For adults, Hazard Index (HI) values ranged from 0.71-0.89 (<1), indicating no significant non-carcinogenic risk (Table 5). However, values approaching unity at PSJ (0.89) suggest Pb exposure is near the threshold of concern. For children, HI values ranged from 2.0-2.5 (>1), indicating potential non-carcinogenic risk. Pb dominated the hazard index, contributing approximately 95% of total HI for children. The primary exposure pathway was ingestion, followed by dermal contact, with inhalation negligible.

Carcinogenic risk: Total carcinogenic risk for Cr and Ni ranged from 1.9×10^{-5} to 2.4×10^{-5} , within

the USEPA acceptable range (10^{-6} - 10^{-4}). This indicates a probability of 19-24 cancer cases per million exposed individuals.

Important caveat: The cancer risk calculation for Cr assumes that all measured chromium is in the hexavalent form [Cr(VI)], which is the carcinogenic species. However, our analysis measured total Cr, and Cr in roadside soils typically exists predominantly as less toxic Cr(III). Therefore, the reported carcinogenic risk for Cr is likely a conservative overestimate; site-specific Cr(VI) speciation analysis is recommended for refined risk assessment.

Table 5: Hazard index (HI) values for adults and children

Population	Location	Season	HI	Risk Level
Adults	PSJ	Wet	0.89	No significant risk
Adults	PSJ	Dry	0.76	No significant risk
Adults	FHJ	Wet	0.74	No significant risk
Adults	FHJ	Dry	0.71	No significant risk
Children	PSJ	Wet	2.2	Potential risk
Children	PSJ	Dry	2.5	Potential risk
Children	FHJ	Wet	2.0	Potential risk
Children	FHJ	Dry	2.3	Potential risk

Corresponding author: OKAFOR Chinonso Patrick

[✉ cporaka.pg@atbu.edu.ng](mailto:cporaka.pg@atbu.edu.ng)

Sustainable Procurement, Environmental and Social Standards Enhancement Centre of Excellence, ATBU, Bauchi

© 2026. Faculty of Technology Education. ATBU Bauchi. All rights reserved.

Figure 3. Non-Carcinogenic Hazard Index (HI) for Adults and Children at PSJ and FHJ by Season

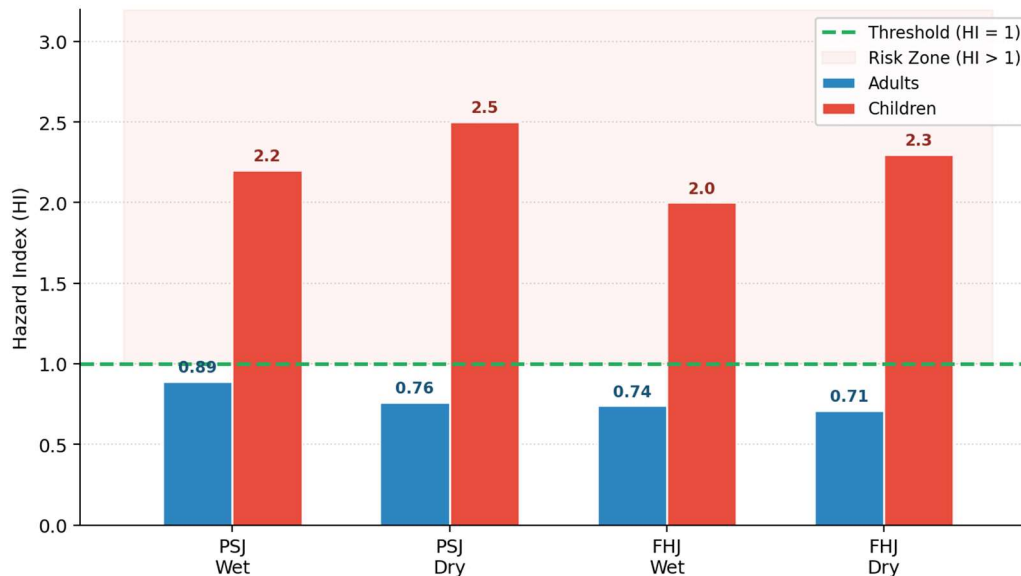


Figure 3. Non-carcinogenic hazard index (HI) for adults and children at PSJ and FHJ by season.

DISCUSSION

Sources of contamination: Several lines of evidence point to vehicular emissions as the dominant source: (1) high enrichment of traffic-related metals (Pb, Cd, Zn); (2) higher concentrations at PSJ with greater traffic density; (3) decreasing concentrations with distance from road (observed but not fully quantified); (4) seasonal patterns consistent with atmospheric deposition; and (5) similarity to other roadside studies globally. Specific sources include historical leaded gasoline combustion and lead-acid batteries (Pb), tire wear (Cd, Zn), brake wear (Cu), and diesel combustion (Ni).

Comparison with previous studies: Pb levels in this study (74.6-85.9 mg/kg) are lower than Kakulu's (2003) report of 281 mg/kg in Abuja's commercial areas, possibly reflecting reduced emissions following the 2002 leaded gasoline phase-out and differences in sampling proximity to roads. However, current levels are substantially higher than Jibrin and Abdullahi's (2019) findings in mechanic workshops (0.8-2.3 mg/kg),

highlighting that direct roadside soils receive greater traffic emissions than workshop soils set back from roads.

More recent studies across Nigerian urban corridors have reported comparable contamination patterns. For instance, Oka et al. (2025) documented elevated Pb and Cd in soils near petroleum-impacted environments in Rivers State, while Ojo et al. (2024) found moderate to high contamination factors for Pb and Zn in farm soils within Abuja metropolis, attributing these to vehicular emissions and urban runoff. These findings reinforce the conclusion that roadside heavy metal accumulation is a persistent issue across Nigeria's rapidly urbanizing areas, with Pb consistently identified as the metal of greatest concern.

Health implications: The finding that children face potential non-carcinogenic risks (HI > 1) is particularly concerning given Pb's neurodevelopmental effects, including reduced IQ, attention deficits, and behavioral problems (Tchounwou et al., 2012). Children's vulnerability

Corresponding author: OKAFOR Chinonso Patrick

✉ cporaka.pg@atbu.edu.ng

Sustainable Procurement, Environmental and Social Standards Enhancement Centre of Excellence, ATBU, Bauchi

© 2026. Faculty of Technology Education. ATBU Bauchi. All rights reserved.



stems from higher soil ingestion rates per body weight, hand-to-mouth behavior, and developing physiology. The absence of significant adult risk does not preclude adverse effects on sensitive subgroups (pregnant women, individuals with pica). Carcinogenic risks within acceptable limits provide some reassurance, though Cr speciation uncertainty warrants caution.

STUDY LIMITATIONS

Self-report bias is not applicable as this was an analytical study. However, limitations include: (1) two junctions may not represent the entire road; (2) six metals analyzed, excluding others (As, Hg); (3) total metal analysis without speciation or bioavailability assessment; (4) health risk assessment using standard assumptions may not reflect actual exposure patterns; (5) cross-sectional design prevents temporal trend analysis.

CONCLUSIONS

This study provides empirical evidence of heavy metal contamination in roadside soils around two major junctions along Lugbe Airport Road, Abuja. The key conclusions are:

1. **Elevated heavy metal concentrations** were observed, with Pb at PSJ (mean 85.9 mg/kg) exceeding the Nigerian permissible limit of 85 mg/kg at selected sampling points. Cd approached regulatory limits (2.65 mg/kg vs 3 mg/kg limit), while Zn, Cu, Cr, and Ni remained below standards.
2. **Vehicular emissions are the primary contamination source**, as evidenced by enrichment patterns (Pb, Cd, Zn highest), traffic density gradients, seasonal variations, and comparison with previous studies.
3. **Significant seasonal and vertical variations** exist: dry season concentrations exceed wet season by 3-11% ($p < 0.05$), and surface soils contain 12-18% higher concentrations than subsurface, indicating ongoing surface accumulation.
4. **Soil quality has deteriorated** at both locations: Igeo classified Pb and Cd as "heavily contaminated" (Class 4), Zn as

"moderately to heavily contaminated" (Class 3), and PLI values > 1 (range 3.4-4.8) confirm overall degradation.

5. **Children face potential non-carcinogenic health risks** (HI 2.0-2.5), primarily from Pb ingestion, while adults show no significant risk (HI 0.71-0.89). Carcinogenic risks for Cr and Ni are within acceptable limits ($1.9-2.4 \times 10^{-5}$).
6. **Police Sign Board Junction requires priority intervention** due to higher traffic density, Pb exceedances, and greater health risks compared to Federal Housing Junction.

RECOMMENDATIONS

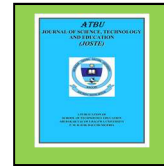
1. Establish a continuous monitoring program for heavy metals along major Abuja roads with annual sampling to track trends
2. Develop Abuja-specific soil quality guidelines accounting for local background concentrations, soil properties, and exposure patterns
3. Enforce stricter emission standards for diesel vehicles (major Cd and Ni sources) and regulate lead-acid battery disposal
4. Consider buffer zones (10-15 m from road edge) for sensitive land uses (schools, playgrounds, residences)
5. Implement weekly street sweeping during dry season and bi-weekly during wet season to remove metal-bearing dust before soil accumulation
6. Improve drainage systems to reduce runoff erosion and contaminated particle transport
7. Cover bare soil areas with vegetation (native metal-tolerant grasses), gravel, or pavement to reduce dust resuspension
8. Post warning signs at PSJ about Pb risks, particularly targeting parents of young children
9. Promote traffic management measures (synchronized lights, roundabouts) to reduce congestion and stop-and-go emissions
10. Conduct public health education campaigns on exposure reduction strategies: hand washing, doormats, wet mopping, covering outdoor food

Corresponding author: OKAFOR Chinonso Patrick

✉ cporaka.pg@atbu.edu.ng

Sustainable Procurement, Environmental and Social Standards Enhancement Centre of Excellence, ATBU, Bauchi

© 2026. Faculty of Technology Education. ATBU Bauchi. All rights reserved.



11. Screen children in the study area (particularly within 10 m of road) for blood lead levels
12. Promote adequate calcium, iron, and vitamin C intake to reduce Pb absorption
13. Advise against gardening/farming within 10 m of road edges, especially for leafy vegetables
14. Practice good hygiene: wash hands after outdoor activities, before eating, and before bedtime
15. Minimize soil ingestion: use doormats, wet-mop floors, keep children's play areas away from road edges
16. Cover outdoor food and water to prevent dust contamination
17. Support community efforts to vegetate bare soil areas and maintain drainage channels
18. Conduct heavy metal speciation and bioavailability studies to assess actual toxicity and mobility
19. Perform Cr(VI) analysis specifically to accurately evaluate cancer risk
20. Expand study to additional locations along Lugbe Airport Road and other major Abuja roads
21. Conduct longitudinal studies to assess temporal trends and intervention effectiveness
22. Investigate heavy metal concentrations in dust, air, and locally grown vegetables for additional exposure pathways

ACKNOWLEDGMENTS

The authors thank the laboratory staff of Technology Partner International (TPI) for technical assistance during sample preparation and AAS analysis. Special thanks to Mr. Ibrahim Abdullahi for his guidance on Atomic Absorption Spectrophotometry procedures. The support of field assistants during sample collection is gratefully acknowledged.

REFERENCES

Alloway, B.J. (2013). *Heavy Metals in Soils: Trace Metals and Metalloids in Soils and their Bioavailability* (3rd ed.). Springer.

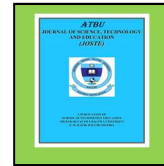
- Jibrin, N.A., & Abdullahi, K. (2019). Analysis of heavy metals in soil of mechanic workshops along airport road, Abuja. *African Journal of Environmental Science and Technology*, 13(4), 156-163.
- Kabata-Pendias, A. (2011). *Trace Elements in Soils and Plants* (4th ed.). CRC Press.
- Kakulu, S.E. (2003). Trace metal concentration in roadside surface soil and tree bark: A measurement of local atmospheric pollution in Abuja, Nigeria. *Environmental Monitoring and Assessment*, 89(3), 233-242.
- Müller, G. (1969). Index of geoaccumulation in sediments of the Rhine River. *GeoJournal*, 2, 108-118.
- NESREA. (2019). *National Environmental (Soil Quality) Regulations, 2019*. National Environmental Standards and Regulations Enforcement Agency, Abuja, Nigeria.
- Oka, O.K., Ojiako, E.N., Okeke, A.P., & Anagbogu, E.N. (2025). Characterization and risk assessment of heavy metals and hydrocarbon sludge in the Nsisioken environment, Rivers State Nigeria. *Journal of Global Ecology and Environment*, 21(3), 110-123.
- Ojo, A.O., Nnamso-Ubokodom, M.E., & Nzekwe, O.F. (2024). Geochemical assessments and human health risk evaluations of selected farm soils within the Abuja metropolis, North-central, Nigeria. *African Scientific Reports*, 3(2), 45-62.
- Tchounwou, P.B., Yedjou, C.G., Patlolla, A.K., & Sutton, D.J. (2012). Heavy metal toxicity and the environment. *Molecular, Clinical and Environmental Toxicology*, 101, 133-164.
- Tomlinson, D.L., Wilson, J.G., Harris, C.R., & Jeffrey, D.W. (1980). Problems in the assessment of heavy-metal levels in estuaries and the formation of a

Corresponding author: OKAFOR Chinonso Patrick

✉ cporaka.pg@atbu.edu.ng

Sustainable Procurement, Environmental and Social Standards Enhancement Centre of Excellence, ATBU, Bauchi

© 2026. Faculty of Technology Education. ATBU Bauchi. All rights reserved.



- pollution index. Helgoländer
Meeresuntersuchungen, 33, 566-575.
- USEPA. (2023). Regional screening levels
(RSLs) - Generic tables. United States
Environmental Protection Agency.
- World Health Organization. (2011). Guidelines for
Drinking-water Quality (4th ed.). WHO
Press.

Corresponding author: OKAFOR Chinonso Patrick

✉ cporaka.pg@atbu.edu.ng

Sustainable Procurement, Environmental and Social Standards Enhancement Centre of Excellence, ATBU, Bauchi

© 2026. Faculty of Technology Education. ATBU Bauchi. All rights reserved.